



HSF Transition: A focus on the next steps in cislunar space

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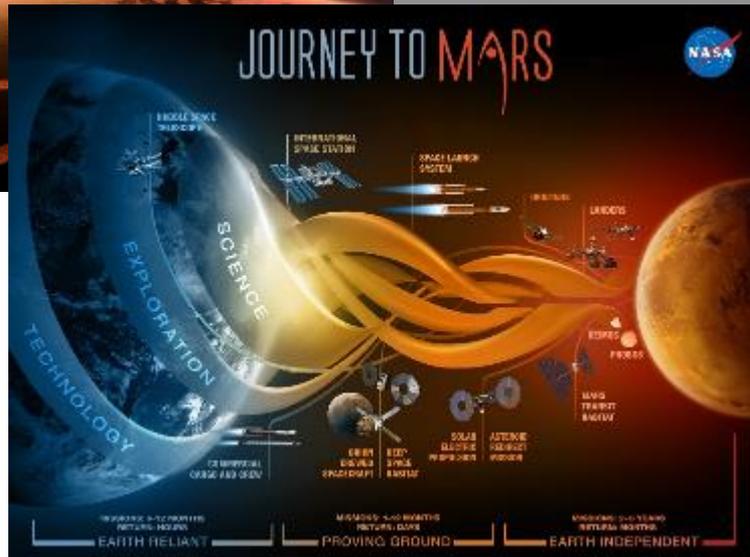
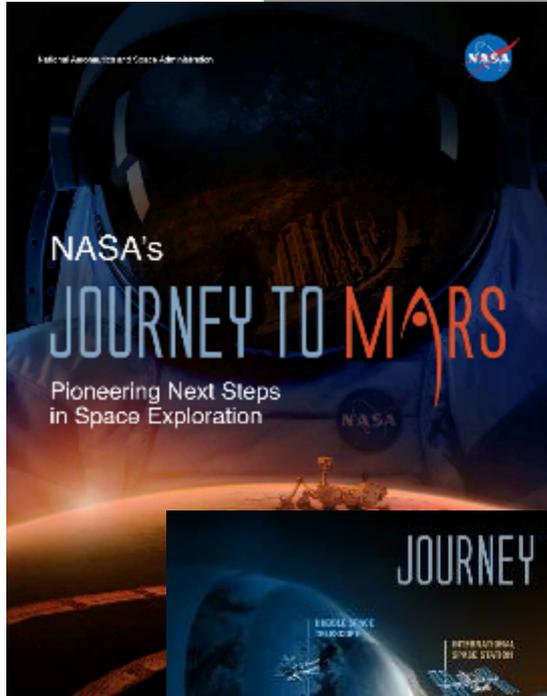
HEO NAC

NASA Headquarters

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Bigger Picture



Near-term execution



Evolution in perspective and in detail

Discussion here at the HEO NAC will inform the next evolution of our plans for the next full NAC later this summer

Transitioning HSF from ISS to Cislunar Space (Earth Reliant to the Proving Ground)



Earth Reliant



Long Duration Human Health & Habitation
Research and Demonstrations

* Currently building plan to demonstrate Mars
habitation systems on ISS

Knowledge & Capabilities

Goal at the end of the
2020s: Mars ready -
One year crewed
expedition(s) in cis-
lunar space

Proving Ground

Short Duration Habitation
& Transportation system validation

Long duration human health & habitation
Validation for Mars transit

Knowledge & Capabilities

Learning how to be Earth Independent

- SLS/Orion performance validation
- Crew autonomous operations
- Crew health and performance research and validation
- Habitation systems performance validation including EVA
- Radiation shielding characterization and validation
- Guidance and navigation in deep space
- Prox ops and docking in deep space
- Breaking the logistics chain
- Reduced reliance on the ground control
- Validating other spacecraft system validation



- **Instead of declaring a definite end date for ISS, NASA will focus on considerations such as**
 - Short term crewed habitation missions are being executed in cislunar space while ISS is still operational and being utilized
 - Exploration research and technology/system development activities requiring ISS as a testbed are essentially complete
 - There is an expanded commercial market and broad private/government/academic demand for LEO-based platforms that are based on private and/or public/private business models
 - Value benefit of the ISS has been sufficiently achieved
 - Maximizing international ISS partnership and participation
 - Safe sustainment of the ISS will remain paramount
- **Based on today's planning and reasonable progress towards our goals, transitioning HSF and ISS could be expected in the mid-2020s**
 - NASA is working with stakeholders, International Partners and industry to develop plans for transitioning the ISS and the Partnership
 - The Partnership should explore possible outcomes for the ISS platform at its' end-of-life
 - De-orbit, disassemble, turn over portions to private industry, maintain government ownership, others ideas

Transition from ISS to Cislunar Space: Framework



Today

Phase 0: Exploration Systems *Testing on ISS*

Ends with testing, research and demos complete*

Asteroid Redirect-Crewed Mission Marks Move from Phase 1 to Phase 2

Phase 1: *Cislunar Flight Testing* of Exploration Systems

Ends with one year crewed Mars-class shakedown cruise

Phase 2: *Cislunar Validation* of Exploration Capability

Mid-2020s

2030

*There are several other considerations for ISS end-of-life

Draft - Top-Level Phase Objectives



Phase 0: Exploration Research and Systems Testing on ISS

- Test Mars-capable **habitation systems** – ECLS, environmental monitoring, crew health equipment, exploration generation EVA suit, fire detection/suppression, radiation monitoring
- Complete **human health & performance** research and risk reduction activities
- Demonstrate **exploration related technologies and operations**
 - Autonomous crew operations
 - Docking, prox ops

enables

- Robotic manipulation technology and techniques demonstrations
- Remote presence technology development and demonstrations
- Earth/space science
- Enable development of LEO commercial market

Phase 1: Cis-lunar Flight Testing of Exploration Systems

- Demonstrate that **SLS and launch processing systems** can insert both Orion and co-manifested payloads into cis-lunar space
- Demonstrate that **Orion and mission operations** can conduct crewed missions in cis-lunar space at least for 21 days
- Demonstrate **Mars-extensible systems and mission operations** that reduce risk for future deep space missions (with EVA) beyond 21 days

enables

- Validate cis-lunar as staging orbits
- Use of high power SEP for deep space missions
- Asteroid related origins of the solar system science objectives
- Demonstrate real-time robotic lunar surface activities
- In situ resource utilization demonstrations

Phase 2: Cis-lunar Validation of Exploration Capability

- Validate **Mars class habitation** and habitation system functionality and performance
- Validate **Mars class human health and performance**
- Validate operational readiness to leave Earth-Moon system via **one year+ “shakedown cruise”** (no resupply/crew exchanges, limited ground interaction, etc.)

enables

- Origins of the universe, lunar rover volatile sample return
- Other scientific or research objectives?



Next slides will focus on a discussion of Phase 1 objectives



Phase 1: *Cislunar Flight Testing* of Exploration Systems

Asteroid Retrieval Crewed Mission Marks Move from Phase 1 to Phase 2

EM-1



OBJECTIVES:

- Demonstrate integrated SLS/Orion capability from launch through recovery in cis-lunar space
- Obtain ascent and in-space environments data
- Demonstrate performance of communications, network, and tracking capabilities
- Demonstrate ground processing and operational support
- Deploy secondary payloads

MISSION ELEMENTS AND CAPABILITIES:

- SLS Block 1 (EM-1)
- Orion
- Secondary Payload deployment

Considerations, Constraints, and Unknowns:

- Initial mission design driven by need to meet flight test objectives



Phase 1: ***Cislunar Flight Testing*** of Exploration Systems

Asteroid Retrieval Crewed Mission Marks Move from Phase 1 to Phase 2

EM-2



OBJECTIVES:

- Demonstrate SLS/Orion crewed cislunar transportation and trajectory capability in cislunar space up to 21 days w/ 4 crew
- Demonstrate co-manifested payload capability in cis-lunar space (~ 5MT or better)

Considerations, Constraints, and Unknowns:

- Initial mission design driven by need to meet flight test objectives
- Initial co-manifesting planning driven by conservative analysis
- Proximity operations under evaluation

MISSION ELEMENTS AND CAPABILITIES:

- SLS Block 1B (EM-2 and subsequent)
- Orion
- Co-manifested capability (in work)



Phase 1: *Cislunar Flight Testing* of Exploration Systems

Asteroid Redirect Crewed Mission Marks Move from Phase 1 to Phase 2

EM-Next 2-3

OBJECTIVES:

- Demonstrate extended crewed operations in cis-lunar space with 4 crew beyond 21 days
- Demonstration of crew health and performance systems particularly exercise, medical, and radiation protection
- Demonstrate deep space EVA capability
- Deploy co-manifested element(s) in cislunar space
- Perform ARCM mission objectives

MISSION ELEMENTS AND CAPABILITIES:

- SLS Block 1B
- Orion
- Co-manifested element(s) with docking, power, propulsion and mission augmentation capabilities to support increasingly ambitious missions in Phase 2
- (ARM robotic spacecraft)

Considerations, Constraints, and Unknowns:

- Mission(s) orbit driven by ARCM mission objectives
- Co-manifesting capability under analysis
- Partner discussions continue on execution of ARM and ARCM missions and co-manifested elements
- Number of additional missions required to execute ARCM dependent on risk buy-down of previous missions and eventual co-manifesting capability

Draft - Phase 1 Flight Test Objectives



CATEGORY	FLIGHT TEST OBJECTIVE
Transportation	Demonstrate Orion's capability to extract co-manifested payload from SLS fairing.
Transportation	Determine Orion's ability to support missions with at least 4-Crew longer than 21 days in conjunction with additional elements.
Transportation	Evaluate Orion's depress/repress for EVA contingency operations.
Transportation	Evaluate Orion's off-axis (tail-to-sun) performance.
Transportation	Evaluate EUS TLI Performance with Orion plus Co-Manifested Payload.
Transportation	Evaluate high-power electric propulsion systems.
Transportation	Evaluate high-efficiency, high-power solar arrays in deep space.
Habitation Working in Space	Demonstrate crew accommodations for Beyond-LEO conditions.
Habitation Working in Space	Evaluate the performance of electrical components in a deep-space radiation environment.
Habitation Working in Space	Evaluate cislunar transit habitat airlock and EVA system servicing accommodation for ability to support contingency EVA operations.
Habitation Working in Space	Evaluate cislunar transit habitat airlock and EVA system servicing accommodation for ability to support nominal deep space mission EVA operations.
Operations Working in Space	Demonstrate transition between crewed and uncrewed operations, including configuration for remote/dormant operations and reactivation for crewed support.
Operations Working in Space	Demonstrate human spacecraft operations in the presence of communications latency.
Operations Working in Space	Demonstrate independent (On-board) mission and trajectory design/planning capability.
Operations Working in Space	Demonstrate Earth-independent deep space navigation.
Operations Working in Space	Evaluate stowage strategies to handle logistics and trash within available stowage volume for deep space missions.
Operations Working in Space	Demonstrate side-by-side human and robotic operations.
Exploration Working in Space	Demonstrate collection and return of geologic asteroid samples.
Exploration Working in Space	Demonstrate research sample acquisition, handling, analysis, and curation requiring environmentally controlled conditions with no cross-contamination permitted.
Staying Healthy	Demonstrate/evaluate space radiation protection and monitoring.
Staying Healthy	Demonstrate/evaluate human health, performance, and environmental health in a hostile and closed environment.
Staying Healthy	Evaluate the effects of deep space on complex organisms, plants, food, medicines, and animal models.

Forward work: Need to parse draft lower level objectives into individual EM missions and co-manifested elements



PROVING GROUND OBJECTIVE DESCRIPTION (EXAMPLES)

Demonstrate SLS ascent, booster separation, core stage separation, Orion and co-manifested cargo insertion into LEO and on cis-lunar trajectory including guidance targeting accuracy. ICPS/EUS burn, engine restart capability & disposal. Deliver Orion, crew & cargo to cis-lunar. Secondary payload deployment from ICPS/EUS.

Crew module ingress, cabin pressure leak check, egress after splashdown. Recovery of flight crew no more than 2 hours after splashdown. Autonomous piloting of spacecraft through ascent, in-space including cis-lunar and entry flight phases with automated and manual control capability.

Ascent to LEO, commit to Lunar trajectory (TLI burn), outbound and return trajectory correction burns (between Earth and Moon), Entry, tending in and exit from cis-lunar orbit (possibilities include Near Rectilinear Orbit (NRO), Distant Retrograde Orbit (DRO), Hybrid Triple). Cis-lunar rendezvous, proximity operations, docking, separation. Control trajectory using OMS engine and SM auxiliary thrusters. CM separation burns, trajectory adjustments prior to Earth re-entry including trajectory correction burn, separation burn following SM jettison, high speed (11km/sec) guided Earth re-entry, Entry Interface and splashdown landing location targeting

Open and evolvable exploration architecture that increases SLS upmass capability to LEO from 10 mT (Block 1) to 20 mT (Block 1B), SLS payload volume from 5m (LVSA) to 8.4m (USA). Crewed duration in space extends beyond 21 days (Orion only capability). Maximum crew size capability increases from 4 to 6 crew. Accomplish commercial and international partner goals and mission objectives in deep space.

Cis-lunar rendezvous, prox ops, docking, undocking, separation. Navigation in LEO using GPS, in deep space using star tracker and DSN. Communication in LEO via SN, in deep space via DSN, ship-to-ship, laser communications. EVA operations including crew suit-up, prebreathe operations, airlock ingress, depress, egress, Extra-Vehicular Operations, ingress, hatch closure, airlock pressurization and maintenance, egress, splashdown. Spacecraft consumables management (propellant, He), power battery/solar array management (insolation, eclipse, LEO, deep space), thermal system balance, maintenance. Logistics, Staging in cis-Lunar including departure, dormancy, reactivation and later return. Cargo operations, storage, transfer, stow, disposal, inventory, maintenance and repair, daily planning, information transfer with Earth, system maintenance, periodic system checks and planning

Crew consumable management (food, water, O₂, nitrogen) and crew health, performance, risk mitigation techniques in deep space environment. Radiation monitoring, crew cabin humidity control, carbon dioxide removal, water quality, food preparation, crew exercise, hygiene, sleep, mental health, telemedicine, medical kit, PPE, smoke/fire monitoring, atmospheric monitoring.

Crew cabin temperature control, Vestibule leak check, hatch opening, ingress, outfitting, egress, hatch closure, vestibule depress, water recycling, atmospheric revitalization, POCO₂ control, O₂ and cabin pressure maintenance. Co-manifested cargo operations, staging in cis-lunar, departure, remote tending, dormancy, reactivation, re-rendezvous and docking

Enable deep space robotic precursor missions, remote observation, imagery & data collection, technology experiments and demonstrations, payload deployments, crew assisted scientific sample return

Crew and autonomous data collection, retrieval including imagery, flight crew medical experiments, in-cabin (CM) pressurized science (short and long duration), external (SM) Unpressurized Cargo (UPC), crew assisted deep space scientific sample return, secondary payload deployment from ICPS/EUS, data return

Advance integrated human/robotic operations via spacecraft command & control, systems maintenance, health & status monitoring. Manual/autonomous command & control of spacecraft, integration with ground team on Earth accounting for time lag, remote operation of uncrewed assets in cis-lunar

EXAMPLES

Discussion

